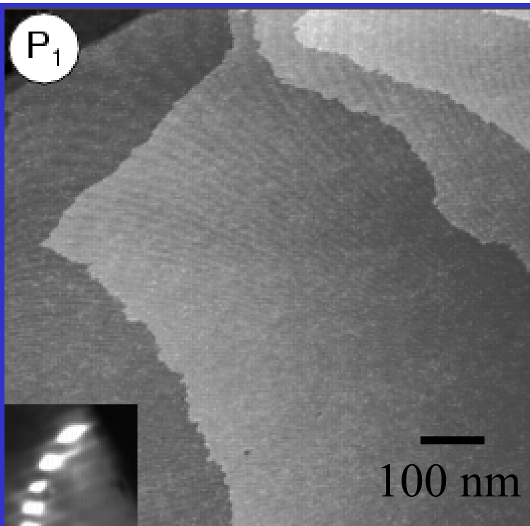
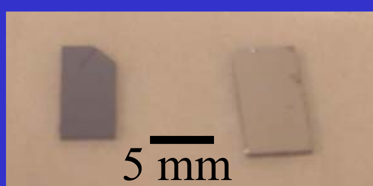
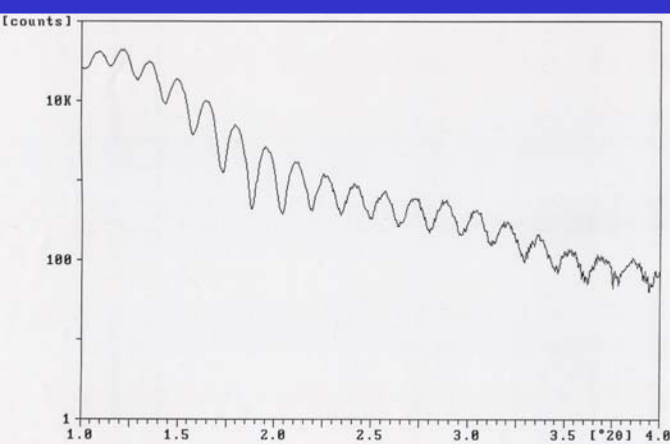
FRG: Spintronics

Paul M. Thibado

DMR 0102755

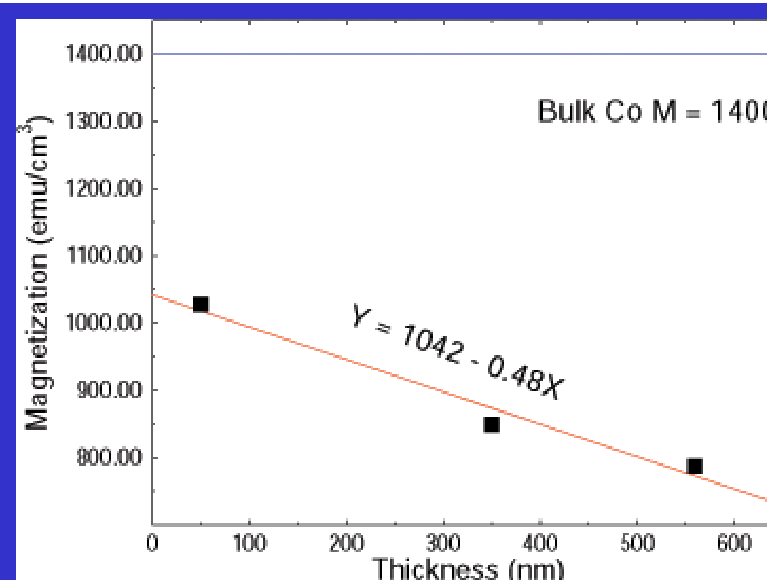






- The objective of this work is to understand the magnetic properties of cobalt metal grown epitaxially on GaAs(001).

- To the left is our evidence for growing a smooth film on a smooth surface. Top: STM image of the surface before growth, middle: optical data before and after growth, and bottom: X-ray reflectivity data showing numerous oscillations indicative of an abrupt interface.



- Above data shows the magnetization of three cobalt films each slightly thicker, and this data is compared to the magnetization of bulk cobalt (top horizontal line).

- What's unusual is that the magnetization drops with increasing thickness. We believe that arsenic is drawn out of the substrate and into the cobalt film.

Aim of the project: Overall, this project is attempting to develop a better understanding of the electron spin-injection process from a ferromagnetic metal into a conventional III-V semiconductor. This specific part of the project is focusing on growing high-quality ferromagnetic cobalt metal films on the GaAs(001) surface. We chose this surface because our group has intimate knowledge of how to prepare it to be nearly perfect. Our procedure allows us to make the surface atomically flat and atomically ordered over lengths of about one micron. We chose to deposit cobalt metal on this surface because our group has successful injected a spin-polarized current into GaAs using cobalt tips in our low-temperature scanning tunneling microscope.

Research results: Top left: Starting GaAs(001) surface as seen using STM and electron diffraction (inset). This is the most well ordered GaAs(001) surface ever prepared. Each gray level represents a single atomically flat terrace separated from the next terrace by a monolayer of GaAs. The sharp electron diffraction spots indicate the surface atoms are extremely well-ordered. Our preparation technique is now used by numerous other groups. Middle left: Before and after optical pictures of the sample coated with cobalt. Often the easiest way to determine the quality of a thin film is simply by looking at its reflective properties, and this film is essentially flawless. Bottom left: X-ray reflectivity intensity as a function of the glancing incident angle for a 50 nm thick cobalt film. The large number of oscillations indicates that the interface between the GaAs and the cobalt is abrupt. Top right: Magnetization of Co films with different thicknesses deposited by e-beam evaporation. The horizontal solid line shown near the top is the magnetization of bulk Co material. Here all of the samples show a lower magnetization value than bulk cobalt. Even more surprising is that the magnetization drops as the film gets thicker. Eventually, one would assume that the magnetization of the film would approach the bulk value as it was grown thicker, but this is not the case.

Significance of this work: The results of this study were unexpected. At the onset, we believed that our nearly perfect GaAs(001) starting surface would yield higher quality cobalt metal films. Still today, we don't know what is wrong with the films. Our best guess is that arsenic is drawn into the cobalt film and lowering the magnetization. We believe some type of chemical transport barrier is needed to make further progress. A few possible future directions include growing the films at lower temperatures (these were grown nominally at room temperature), growing the films at a higher deposition rate (these were grown at 0.1 nm/min.), and growing a third material that is only a few monolayers thick prior to the deposition of the cobalt film.

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Girl Scout Troop #87
Fayetteville, Arkansas

Earns Science “Try-It” Patch

Girls Scout troop 87, Fayetteville, Arkansas visits Prof. Thibado's research laboratory. The purpose was to learn some of the wonders of science and learn about the critical need for women to become physicists.

This event was very successful – just look at their faces. Girl Scout troops represent a large nationwide pool of young girls very eager to learn new things and naturally chaperoned by their mothers. Thus, they are an easy group to tap into and there are hundreds in Northwest Arkansas. These girls also received a science "try-it" patch for there activities.

The days events were simple and fun. We gave them a snack. They watched some liquid nitrogen demonstrations. We had them perform four different hands experiments [(1) build an atomic model to take home, (2) make a marshmallow expand in size by removing the air around it, (3) spot weld two metals strips together, and (4) identify an image under a high-powered optical the microscope]. Then, we took them to a classroom and had them participate (using individual transmitters) in a question and answer session. We showed them statistics on how few women become physicists and how there is a critical need at the national level for them. We all agreed that science is fun and it's cool to become a scientist. Finally, we empowered them with dialog to combat peer-pressure and stay on a science track as they move into the difficult middle school years ahead. The girls were so moved by the discussion that several of them (including some mothers) are certain that this is what they will pursue for their career.